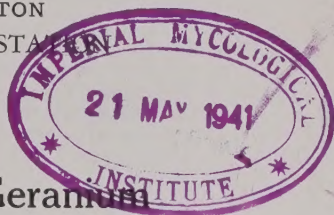


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STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
Pullman, Washington

Division of Plant Pathology



Leaf Curl and Mosaic of Geranium

by
Leon K. Jones



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¹ In cooperation with the State Committee on the Relation of Electricity to Agriculture.

² In cooperation with the United States Department of Agriculture.

³ On leave.

LEAF CURL AND MOSAIC OF GERANIUM¹

Leon K. Jones

INTRODUCTION

Leaves of geranium (*Pelargonium hortorum* Bailey) showing symptoms of leaf curl were sent to the Department of Plant Pathology from Olympia and Touchet, Washington in 1922. This disease was first recognized in Spokane in 1934 and since that date has been generally observed in greenhouses in Washington.

Mosaic of geranium was first recorded in Washington in a greenhouse in Spokane in 1937. Further observations have shown this disease to be prevalent in many greenhouses in the state.

Leaf curl and the mosaic diseases have been observed by the author in Victoria, British Columbia and in Madison, Wisconsin. The former disease has been reported as present, but comparatively rare, in Ontario, Canada (1)², and has also been noted on geranium received from New Jersey in 1938.

The presence of leaf curl and mosaic in geranium cuttings purchased in California and eastern sections of the United States by growers in Washington indicates that the two diseases are fairly common in this country.

A disease of geranium, reported in New Jersey in 1893 (4), as dropsical pelargonium, or dropsy, agrees in all essentials with leaf curl.

A leaf disease of geranium was described in Germany in 1926 (10) as "Kräuselkrankheit," and in England in 1932 (8) as leaf curl. Further reports (2, 3, 5, 6, 7, 9, 12, 13) indicate that they are identical with the leaf curl disease observed in Washington.

Two virous diseases of geranium in addition to leaf curl have been reported from Czechoslovakia (2), namely: aucuba mosaic which apparently does not affect the growth of the host plant; and an interveinal chlorosis which appears to be similar to the mosaic disease observed in Washington.

A mosaic of geranium, the virus of which was transmitted by aphids (*Aphis gossypii* Glover), was produced in Florida (14) by inoculation with celery virus 1. It is considered that the celery virus 1 is the

¹ Grateful acknowledgment is made to the owners of greenhouses in Spokane for their cordial cooperation.

² Reference is made by number to Literature Cited, p. 19.

same as or closely related to cucumber virus 1 and the lily mosaic virus.

Curly top of geranium, which is characterized by clearing of the veins, inward rolling of the leaves, and chlorosis of leaves and stems (11) is different from either leaf curl or mosaic.

SYMPTOMS

Leaf Curl

Irregular to circular, chlorotic areas, $\frac{1}{2}$ to 5 mm. in diameter, which often cause ruffling, crinkling, malformation, and dwarfing of the foliage (Figures 1, 2 and 3), are characteristic effects. The centers of the chlorotic spots may become brown with a chlorotic border, and severely affected leaves may become yellow and drop. Brown, elongated, corky, raised, necrotic areas often develop on the petioles and stems, and in extreme cases the entire top portion of the plant may

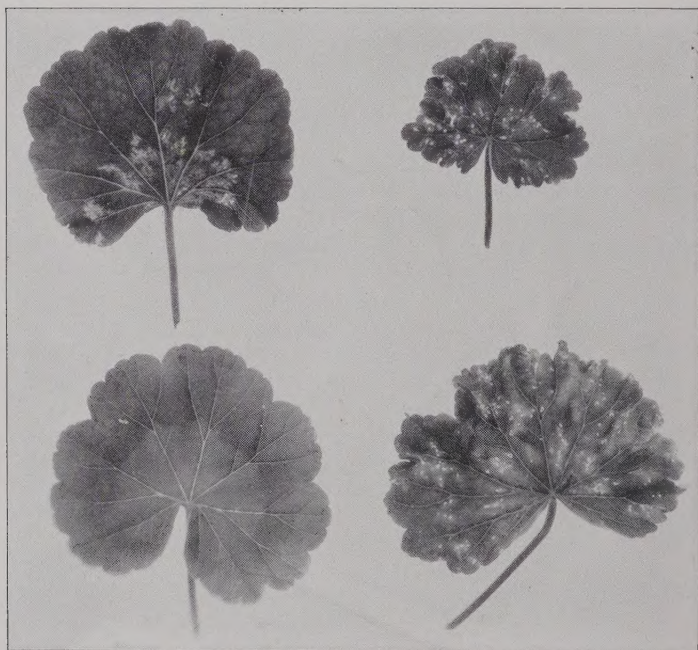


Fig. 1. Spotting of geranium leaves caused by the leaf curl virus. Lower left leaf is healthy.



Fig. 2. Leaf curl symptoms on Michell geranium leaves.



Fig. 3. Geranium leaf curl showing as chlorosis and malformation of foliage.



Fig. 4. Geranium leaf curl showing as spotting and necrosis of foliage and necrosis of stems. Lower right shoot is healthy.

turn brown and die (Figure 4). The disease ordinarily appears in severe form during the spring months, often disfiguring and dwarfing the plants to such an extent that they are unsalable. Severely affected plants usually outgrow the disease during the summer months and ap-

pear healthy, but cuttings taken from such plants will show the disease the following spring.

Mosaic

This disease is characterized by a mottling of the foliage with light-green and dark-green areas (Figure 5). The light areas are usually interveinal with the darker-green areas along the veins. Portions only of leaves may show the mottling, but in other cases the entire leaf is affected. Infected plants are usually dwarfed in leaf size and length of internodes. As is the case with the leaf curl disease, although not as pronounced, mosaic symptoms are masked during the summer months and become most evident during late winter or spring.

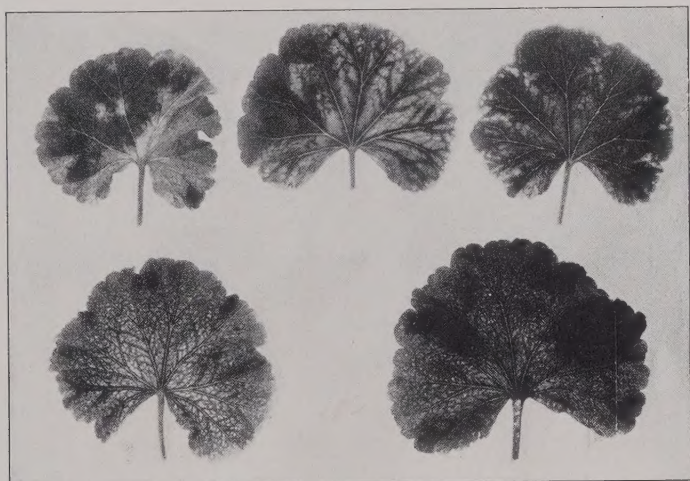


Fig. 5. Geranium mosaic: Variation in symptoms noted on plant infected by grafting.

ECONOMIC IMPORTANCE

Leaf Curl

Leaf curl is generally present in greenhouses in Washington but the percentage of plants showing symptoms varies from a trace to as high as 45 per cent.

Leaf curl was very destructive in one greenhouse in Spokane in 1937, and detailed counts on the prevalence of the disease in this greenhouse during the seasons of 1937, 1938, and 1939 are recorded in

Table 1. The Prevalence of Leaf Curl in Geranium Varieties in One Greenhouse in Spokane, Washington

Variety	May 8, 1937			1938				April 23, 1939	
	Plants observed	Plants showing symptoms	%	Plants showing symptoms		Plants observed	Plants showing symptoms		Plants showing symptoms†
				2/19	3/23	4/22*	Number	%	
Enchantress Fiat									
Fiat	1385	11.1		0.0	5.6	25.1	36		
Gloede	92	43.5		2.4	13.3	22.0	3752		1182
Gorgeous				1.1	8.0	20.6	270		241
Irvington Beauty	55	18.2		0.0	8.3	13.6	132		98
Leslie Redford	16	6.3		3.5	28.5	38.7	115		110
Louise	141	1.4		0.0	6.7	20.1	18		94
Mathew's Pink				0.7	3.9	9.6	278		10
Michell	897	8.4		0.0	0.0	9.8	41		1762
Michell Improved	119	11.8		0.3	22.3	35.6	3449		9.2
Madam Buchner	64	21.8					184		111
New Fiat	357	14.6		1.1	11.6	19.1			14.4
S. A. Nutt	991	2.5					8848		8390
Pink Barney	160	3.8		0.6	3.6	12.2			2.4
Radio Red	957	6.6		5.1	15.8	17.6	98		
Ricard	127	11.0		0.0	5.8	21.7	207		75
Salmon Ideal				0.5	7.7	14.8	5111		2804
Variegated Nutt	141	0.0		0.3	12.9	27.2	1919		
Viaud	658	3.8					409		
Total and Average	6160	8.0		1.2	6.7	13.6	26867		14867
				0.8	8.0	16.0			6.3

* The stock developed in 1939 was produced from cuttings made from plants selected on May 5, 1938 as showing no symptoms of the disease.

† In 1938, 8 per cent of the plants observed were thrown away as unsalable but only 3.2 per cent were unsalable in 1939 following the selection of propagation stock in 1938. Further selection of stock for propagation in May, 1939 gave less than 1 per cent of the plants affected with leaf curl in the spring of 1940.

Table 1. The disease was present in all the varieties observed, except the variegated Nutt, which was also found to be free from leaf curl in two other greenhouses. Diseased scions of other varieties grafted on variegated Nutt plants, however, have shown this variety to be susceptible.

The prevalence and severity of the disease varied with the different varieties but Fiat, Gloede, Michell, and Viaud appeared to be more severely affected than Louise, Mathew's Pink, Madam Buchner, S. A. Nutt, Radio Red, and Ricard. About half of the plants or a total of 2620 that developed leaf curl in 1938 and 1939 were discarded as unsalable, amounting to 8 per cent in the former year and 3.2 per cent in the latter.

Mosaic

Although mosaic is generally present in greenhouses of Washington, it is less prevalent and less injurious than leaf curl. The slight to moderate amount of dwarfing does not materially affect the sale of the plants. Records from six greenhouses in Spokane showed the percentage of affected plants to vary from 0 to 40 (Table 2). The disease appears to be more prevalent in the greenhouses in the vicinity of Seattle and Tacoma, Washington than it is in the eastern part of the state.

Table 2. The Percentage of Mosaic in Geranium Varieties. Spokane, Washington May 2, 1938

Varieties observed	Greenhouses observed					
	1	2	3	4	5	6
Beauty of Poitevine	4	3			10	
Fiat	8	4	5	15		1
Gloede	0					1
Michell	1	6	40	20	1	1
Radio Red	0	6	2		1	0
Kovalevsky*		15				
Gorgeous†			0			4

* Cuttings from California, fall of 1937.

† Cuttings from eastern part of U. S., fall of 1937.

ETIOLOGY

The symptoms shown on mosaic-affected plants were characteristic of a virous disease; however, those shown by leaf curl-affected plants led to the conclusion that this disease might be caused by a bacterial organism, a virus, insects, or even unfavorable growing conditions. Attempts to determine the nature of leaf curl in the preliminary

studies included attempted isolations of an organism from diseased areas, observations on insect prevalence, spraying with fungicides, grafting, and mechanical inoculations.

Attempted Isolations of a Pathogen

A large number of plants severely affected with leaf curl were collected in Spokane and brought to the greenhouse in Pullman during April and May of 1937. Numerous microscopic observations of diseased leaf areas failed to show the presence of any causal organism. Forty-six attempts were made to isolate an organism from diseased leaf and stem areas according to the following technique: Small portions of diseased leaf and stem tissue were dipped in 95 per cent alcohol followed by immersion for one minute in mercuric bichloride, 1-1000, and then washed in sterile distilled water. The tissue was macerated in 2 cc. sterile water blanks, then added to tubes of potato-dextrose agar which was poured into sterile petri dishes. Since but one plate contained a few colonies of a yellow bacterium, while the other 45 remained sterile, it was concluded that a bacterial organism was not the cause of the disease. During the early period of observation of the leaf curl disease, 10 affected plants were sprayed with Bordeaux mixture, 4-4-50, and 121 with Burgundy mixture, 4-6-50, while 34 plants were left untreated. One-half per cent penetrol was added to each spray as a spreader. The sprays showed no value in checking the development of the disease and no injury resulted.

Inoculation Studies

In order to test the possible virous nature of leaf curl and mosaic, series of graft and mechanical inoculations with diseased tissue were made on healthy plants. The first grafts were made by winding the inserted cleft union with several kinds of tape; most of the grafts, however, failed to grow. A very successful method of grafting was finally devised which consisted of using a spring clothespin to hold the union of the scion and stock (Figure 6). The plants were placed in a moist chamber for five to seven days after the grafts were made and then removed to a bench in the greenhouse at which time the clothespins were removed. The healthy geranium plants used in the transmission studies had been under observation for four to five years and had never shown any symptoms of leaf curl or mosaic. Disease-free geranium seedlings were also used in the tests. The usual swab-pot label-carborundum method of inoculation was used in the attempt to transmit the viruses by mechanical inoculation.

The results of the inoculation tests (Table 3) show that the two viruses were transmitted to healthy geranium plants by grafting but were not transmitted to tomato by grafts nor to geranium, tomato, or tobacco plants by mechanical inoculation. The period of incubation



Fig. 6. Clothespin method of grafting for transmission of geranium leaf curl and mosaic.

from the time that the grafts were made until symptoms appeared on inoculated plants varied from 28 to 40 days with each of the viruses.

Insect Transmission

Insects, including aphids and plant bugs (*Lygus* sp.), have been mentioned in the literature as possible carriers of the leaf curl virus (9). No insects infesting the common geranium except the cyclamen mite have been noted on geraniums in the greenhouses of Spokane. Mite injury has been noted frequently, but the symptoms are distinct from those associated with leaf curl or mosaic. Ten leaf curl-affected geraniums were placed in an insect-proof cage with 10 healthy plants for 25 days in May, 1937 with the thought that any insects present on the diseased plants would migrate to the healthy plants. No symptoms of leaf curl were observed on the healthy plants four months later. Aphids were noted in abundance on Lady

Table 3. Summary of Inoculation Tests with Leaf Curl and Mosaic of Geranium

Inoculum from affected geraniums	Variety inoculated	Method of inoculation	Plants inoculated*	Plants infected
Leaf curl	Madam Buchner	Graft	57	12
Leaf curl	Geranium seedlings	Graft	10	5
Leaf curl	Tomato plants	Graft	20	0
Leaf curl	Madam Buchner	Mechanical	85	0
Leaf curl	Fiat	Mechanical	8	0
Leaf curl	Geranium seedlings	Mechanical	50	0
Leaf curl	Tomato plants	Mechanical	40	0
Leaf curl	Tobacco plants	Mechanical	15	0
Mosaic	Madam Buchner	Graft	22	10
Mosaic	Tomato plants	Graft	10	0
Mosaic	Tomato plants	Mechanical	25	0
Mosaic	Fiat	Mechanical	8	0
Mosaic	Geranium seedlings	Mechanical	52	0
Mosaic	Tomato plants	Mechanical	40	0
Mosaic	Tobacco plants	Mechanical	15	0

* A similar number of plants in each test were not inoculated as controls. None of the control plants developed either leaf curl or mosaic symptoms.

Washington pelargoniums (*P. domesticum* Bailey) in a greenhouse in Spokane in May, 1938. These infested plants were moved to the greenhouse in Pullman, and the aphids transferred to leaf curl- and mosaic-affected geraniums. The aphids would not feed on the common geraniums, however, and migrated from the plants readily, which made it impossible to test the aphids as possible virus carriers. Leaf hoppers (*Cicadula* sp.) were observed in abundance on geraniums. A large number of the leaf hoppers were caught in glass vials and placed on 10 healthy geranium and 10 tomato plants in an insect-proof cage. The tomato plants showed no symptoms of disease two months later, and the geranium plants showed no symptoms four months later.

Seed Transmission

Seeds from plants affected with mosaic and from others affected with leaf curl were used to start 276 seedlings, 126 from mosaic plants, and 150 from leaf curl plants. None of these seedlings showed symptoms of either disease, although they were grown in the greenhouse for 10 months.

Natural Dissemination

A trial planting of healthy and leaf curl-affected plants was made in Pullman during the summer of 1937 to determine the possibility of

field spread of the virus. Eight rows of five healthy plants each were alternated with eight rows of five leaf-curl plants each. The plants remained in the field from June 6 to September 20 at which time they were placed in a bench in the greenhouse in the same order as the field planting. The symptoms of leaf curl disappeared on the leaf curl-affected plants during the summer and reappeared in the greenhouse as follows: 16 plants showed symptoms in December; 29 in January; 33 in February; 33 in March; 36 in April; 38 in May; and only two plants showed no symptoms at the end of the test on June 9, 1938. None of the 40 healthy plants showed symptoms of leaf curl during the test, which indicates that the virus was not naturally transmitted from the diseased to the healthy plants in the field or greenhouse.

The same leaf curl-affected plants used above that had been kept in the greenhouse during the winter, as well as some younger diseased plants, were placed in the field June 9, 1938. Three rows of healthy plants were alternated with three rows of leaf curl-affected plants and one row of mosaic-infected plants in the field planting. Fifty to 55 plants were placed in each row. Symptoms of mosaic and of leaf curl

Table 4. Tests to Determine the Natural Transmission of Leaf Curl and Mosaic in the Field

Source of cuttings*	Cuttings made†	Plants affected‡	
		Leaf curl	Mosaic
	Number	%	%
Madam Buckner			
Health row near mosaic row	165	3.0	0.6
Health row between leaf curl rows	210	3.3	1.4
Alternately made with mosaic cuttings**	167	6.0	1.2
Alternately made with leaf curl cuttings**	124	2.4	0.0
Fiat			
Healthy row near mosaic row	129	0.7	2.1
Healthy row between leaf curl rows	103	2.9	3.8
Mixed varieties			
Mosaic row	176	0.6	98.9
Leaf curl rows	330	66.6	2.4

* Alternate rows of healthy and diseased plants in the field.

† Cuttings made September, 1938 from plants that had grown in the field during the summer.

‡ Rooted cuttings were potted and grown in the greenhouse until May, 1940.

Plants showing symptoms were rogued when observed.

** Cuttings from healthy plants were prepared for propagation alternately with cuttings from mosaic- or leaf curl-affected plants to determine the possibility of the viruses being transmitted by the cutting knife.

practically disappeared from the affected plants during the summer. Cuttings were made from the diseased and healthy plants in September, 1938, and the rooted cuttings were potted and grown in the greenhouse until May, 1940. The results of these tests (Table 4) show a low percentage of natural transmission of the leaf curl and mosaic viruses to healthy plants in the field, and that the viruses were not transmitted in the preparation of the cuttings for propagation.

FACTORS AFFECTING EXPRESSION OF LEAF CURL SYMPTOMS

The maximum expression of symptoms of leaf curl appears ordinarily during March, April, and May in the greenhouse, but affected plants may show slight or no symptoms of the disease for most of the year. Severely affected plants when placed in the field usually outgrow the symptoms during the summer so that little or no evidence of the disease is apparent in August and September when cuttings are made for the next year's crop. Healthy plants infected by grafting with a diseased scion have always shown symptoms of the disease in 30 to 40 days after grafting, regardless of the season when the graft was made.

The seasonal appearance of symptoms indicates that some environmental factors or cultural practices may be responsible for symptom development. Accordingly, a number of tests were made to determine the effect of temperature, light, and nutrition upon the activity of the virus in the plant.

Temperature

Cuttings were made from leaf curl-affected plants in September and 100 of the potted geranium plants were placed in each of two sections of the greenhouse on January 11, 1938, one held at 50° F. and the other at 70° F. None of the plants had shown leaf-curl symptoms previous to the beginning of the experiment. On March 22, 1938, seven plants in the 50° house and four plants in the 70° house showed symptoms of leaf curl. These results showed that increased temperature was not a determining factor for symptom expression.

Light

At the time the above test was being made, 50 of the infected, symptomless plants were placed in each of the 50° and 70° sections of the greenhouse, where they were subjected to an increase in light. One 150-watt lamp was placed over each 16 square feet of surface to be illuminated and allowed to burn from 5:00 P.M. until 9:00 P.M. each day. Two of the plants at 70° and four of the plants at 50° showed symptoms on March 22, 1938, which would indicate that increased light is not a major factor in causing symptom expression.

Nutrition

March, April, and May is the time when the plants are becoming pot bound and also when bright clear weather increases the temperature and dries out the pots quickly in greenhouses. At this time the larger foliage area makes an increased demand on the root system for water and nutrients. Plants that had been allowed to send their roots through the bottom of the pot and become established in the bench soil were less affected with leaf curl than those that were definitely pot bound. Plants that were moved or repotted often showed a higher percentage with evident symptoms than those which were not.

Six badly diseased plants were repotted from 4-inch to 6-inch pots on March 24, 1938. The new growth on these plants showed only slight symptoms on May 2, and were so little affected on May 12, 1938 that they were considered salable.

Symptomless plants, infected with the leaf-curl virus, were transplanted from a bed to pots in the greenhouse October 6, 1938. Fifteen of the 80 potted plants showed symptoms of leaf curl within one month after transplanting, which would indicate that the injury to the root system greatly influenced symptom expression.

A test of the value of different treatments was made in a commercial greenhouse March 24, 1938 (Table 5). The severely affected

Table 5. The Value of Treatments on Geranium Plants Severely Affected with Leaf Curl

Treatment*	Recovery from symptoms	
	April 7	April 22
Manure water solution	Good	Good
Vigoro, 1 lb. to 10 sq. ft.	Slight	Slight
Borax, 1-800 solution	None	None
Copper sulphate, 1-800 solution	None	None
Iron sulphate, 1-800 solution	Slight	Slight
Plants repotted	Slight	Slight
Control	None	None

* Each treatment was made March 24, 1938 on 18 plants of Fiat and S. A. Nutt varieties except that the manure water was further applied to 59 Michell plants.

plants were watered with solutions of manure, Borax, copper sulphate, and iron sulphate, or an application of Vigoro was watered into the soil. A similar number of plants were repotted from 4-inch to 6-inch pots and watered and the same number of plants as controls were watered only. Eighteen plants of each of the varieties Fiat and S. A. Nutt were given each treatment except that 59 Michell plants were

treated with manure water. These results (Table 5) show that the addition of manure water to the soil in the pots caused the plants to outgrow leaf-curl symptoms in four to six weeks and that the application of Vigoro and iron sulphate as well as repotting the affected plants was of slight value in reducing symptoms.

Since the application of manure water caused the affected plants to produce new foliage without leaf curl symptoms, a test was devised to determine whether a shortage of nitrogen, phosphorus, or potassium might induce the appearance of symptoms.¹

Thoroughly washed, neutral peat was used as the medium in which the virus-infected plants were grown. One half of the plants were grown in glass pots without drainage, and one half were grown in ordinary tile pots that were placed in a tile dish that held the drainage. The plants used in the experiment were transplanted from a raised bench in the greenhouse after having failed to show symptoms, through the summer months, and were from the same lot of plants used in testing the effect of light and temperature discussed above. All the soil was washed from the roots of the plants before planting in the peat, after which the plants were watered at frequent intervals with one of the following solutions: complete nutrient, complete minus nitrogen, complete minus phosphorus, and complete minus potassium. Twelve plants known to be free of the virus and 12 symptomless plants known to carry the virus were treated with each solution. The experiment was started October 6, 1938 and concluded March 15, 1939. During the test none of the healthy plants showed symptoms of leaf curl, and the following percentages of the affected plants showed symptoms in the different nutrient solutions: Complete, 33 per cent; minus nitrogen, 42 per cent; minus phosphorus, 50 per cent; and minus potash, 50 per cent. The results of the tests with nutrient solutions show that shortages of nitrogen, phosphorus, or potash were not marked determining factors in causing the appearance of symptoms. The percentage of plants showing symptoms was somewhat less in the complete nutrient solution, but the small number of plants under observation makes the significance of the difference quite doubtful.

Fluctuation in Moisture Supply

Since the symptoms of leaf curl show to the greatest extent in the spring months, it appeared that extreme fluctuations in moisture supply might be a determining factor. Leaf curl has been very destructive in one greenhouse in Spokane where concrete pots are used instead of the ordinary tile pot. The greater porosity of the concrete pots allows for rapid loss of water and greater fluctuations of water supply than is the case with tile pots. A test was made to determine the

¹ Acknowledgement is made to Dr. L. C. Wheeting, Research Professor of Soils, for cooperation in conducting these tests.

effect of concrete pots and fluctuation of water supply by potting virus-infected, symptomless plants in tile and concrete pots. Twenty of each type of pot were placed on boards, and 20 of each were placed on the soil in ground benches. The soil in the pots was allowed to dry thoroughly before watering. The plants were from the same lot as those used in the nutrient solution experiment, and the tests were made at the same time. The following percentages of the plants showed symptoms when discarded January 21, 1939: Concrete pots on boards, 45 per cent; on soil, 50 per cent; tile pots on boards 65 per cent; and on soil, 58 per cent. The plants in the pots on the soil extended their root systems through the hole in the bottom of the pot into the bench soil. Such plants had a more nearly uniform moisture supply than those grown on the board foundation. No material difference in the number of plants showing symptoms or the rate of symptom appearance was observed in the test.

One of the main difficulties encountered in the investigations was to determine whether a geranium plant was a symptomless carrier of the leaf curl virus. The only certain method was by grafting a scion from the questioned plant upon a known healthy plant. In all cases of such a graft with a virus-infected scion, symptoms appeared on the healthy plant 30 to 40 days after grafting. It was considered that possibly symptoms could be made to appear on rooting cuttings if the cuttings were placed in solutions deficient in nutrients. Accordingly, 27 fresh cuttings of healthy and virus-infected plants were placed in each of the following nutrient solutions: Complete nutrient; complete minus nitrogen; complete minus phosphorus; and complete minus potash. Fifty to 75 per cent of the cuttings rooted in all the solutions, but no leaf curl symptoms were observed on any of them.

CONTROL

The application of manurè water to the soil around affected plants was of considerable value in reducing symptoms; however, this treatment acted only as an aid in making the plant salable (Table 5). Observations in the greenhouses as well as tests to determine the natural spread of the leaf-curl and mosaic viruses (Table 4) indicate that the increase in percentage of affected plants from year to year is caused, largely, by the use of diseased mother stock in propagation. Most growers pay little attention to the selection of mother stock. In fact, it is commonly noted that the better stock is sold and the poorer, unsalable stock is often used for the planting from which cuttings are made for the next year. If sufficient cuttings are not supplied from the unsalable stock, it is a common practice to obtain others from the somewhat frosted plants in parks and cemeteries.

The value of selecting symptomless plants from the stock in the greenhouse early in May, before the general sale of plants, was investi-

gated in one large greenhouse in Spokane. Eight per cent of the plants in this greenhouse showed symptoms of leaf curl in 1937, and this increased to 16 per cent in 1938 (Table 1). Sixteen hundred symptomless plants were selected from the stock and placed in the field during the summer of 1938. All cuttings for the next year's crop were made from the planting of selected stock. The percentage of affected plants in the greenhouse in 1939 was reduced to 6.3. These results show that a marked reduction in losses from the disease was obtained by selecting symptomless mother stock for propagation. It is also apparent that the disease was not eliminated by this procedure since many of the selected plants were probably carriers of the virus with no visible symptoms at the time selection was made. It would, therefore, be advisable to continue the selection process over a period of years if the disease is to be eliminated.

Another grower in Spokane maintains the stock geranium plants the year around in a bench in the greenhouse. Cuttings are made at frequent intervals during the year in order to build up sufficient stock for the late spring market. The plants in the stock bench showed 18 per cent mosaic and 5 per cent leaf curl when first observed during the spring of 1937. All diseased plants were rogued from this bench as observed during 1938 and 1939 and replaced with healthy plants. During the spring of 1940 only a trace of either disease was noted in the stock bench, and the stock in that greenhouse was practically free of mosaic and leaf curl.

SUMMARY

Leaf curl and mosaic are important virous diseases of geraniums which occur in greenhouses of Washington.

The viruses are readily transmissible from diseased to healthy geraniums by grafting methods but are not transmitted to geranium, tomato, or tobacco by mechanical inoculation. No insect transmission has been observed, although a low percentage of natural dissemination has been recorded in field plantings. The viruses were not transmitted in the seed or by the knife in making cuttings for propagation.

The appearance of severe symptoms of leaf curl during the spring and masking of symptoms during the summer and winter indicates that cultural and environmental factors influence symptom expression.

Varying temperatures from 50 to 70° F., increasing the length of day with electric light and depleting the amount of available potash, nitrogen, or phosphorus, did not influence the appearance of symptoms.

The application of manure water, and to a lesser extent the use of Vigoro or iron sulphate on the soil around severely affected plants caused the plants to outgrow leaf curl symptoms.

During a three-year period marked reduction in the percentage of plants affected with leaf curl was obtained by carefully selecting symptomless plants that were grown in the field during the summer for fall propagation.

Nearly complete control of mosaic and leaf curl was obtained by carefully roguing diseased plants from a bed of stock that remained in the greenhouse for three years and making all cuttings from the rogued bed.

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